

Chapter - 7
CONCLUSION AND
FUTURE RESEARCH

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CONCLUSION

Smart grid is the most ingenious, advanced and revolutionary technology of present era. The passive power grid is envisioned as an integration of electrical and ICT infrastructure for full duplex communication through design and deployment of Smart grid technology. Smart grid facilitates a continuous exchange of information between various stakeholders. The most important feature of Smart grid technology is an active participation of consumers. Smart grid consists of sensors, actuators, communication transceivers, network devices etc. for integration of ICT with electrical infrastructure. Communication infrastructure is an inevitable component of Smart grid technology. Smart grid communication infrastructure is a combination of hierarchical and heterogeneous networks. It consists of HAN, NAN and WAN. This research work focuses on demand side management of Smart grid communication infrastructure. Various wireless and wired communication standards are explored in the thesis.

A cross layer approach is a modification of traditional layered design approach through ‘‘Collaborative Optimization’’. For Smart grid technology, this approach is a very essence of optimization for various hierarchical communication networks as well as protocols. This research work includes optimization of various parameters of IEEE 802.11 standard for performance enhancement. The results depict that cross layer optimization can enhance the performance of HAN and NAN. It is apparent from the results that in some cases, such as frame aggregation and RTS, a collaborative optimization of more than one parameters can enhance the performance or overcome the performance degradation.

The research work contains design and implementation of Smart microgrid communication infrastructure using PAN, LAN and WAN. The prototype is developed using IEEE 802.15.1, IEEE 802.11 and IEEE 802.3 standards for experimental validation of proposed Smart microgrid architecture. The real time readings are included in chapter 5. The local server can be accessed at 192.168.1.177. The prototype also includes validation of IoT concept through webpage development in WAN.

A dedicated website “smartenergy.dlinkddns.com” is developed for monitoring and control of real time operation of developed prototype.

The developed prototype is successfully implemented and tested for real time operation and management of all three energy sources.

The research work explores actual hierarchical Smart grid infrastructure through real time monitoring and control of all three systems. The website is developed using dynamic IP address by acquiring a subdomain. An actual implementation of IoT based Smart grid infrastructure can be realized through static IP.

Integration of various electronics devices, communication transceivers, and electrical equipment causes various EMI threats. Electromagnetic compatibility of various Smart grid devices and equipment can be analyzed for safe and reliable operation of grid. ICT network is vulnerable to cyber threats. Cyber security of Smart grid communication network must be dealt differently as it is an integration of various hierarchical network devices and components. WSN security is the most crucial and challenging aspect of Smart grid cyber security as it is extremely vulnerable to cyber threats due to its limited storage and computational capabilities. WSN is also vulnerable to physical tampering as the sensor nodes are placed randomly as well as enormously. Realization of Smart grid technology imposes numerous challenges to be addressed. This thesis covers theoretical aspects, hardware implementation and simulation of Smart grid communication infrastructure.

The research work explores the development of prototype for validation of theoretical aspects. A web link is also developed for IoT development using dynamic IP which keeps changing. However the static IP can be acquired for actual realization of IoT applications. EMI and cyber security threat analysis are included as open ended issues which can be addressed as a future research.

The outcome of the conducted research work can be briefly summarized as follows.

- Smart grid technology consists of layered architecture with amalgamation of various communication standards. It consist of HAN, NAN and WAN. The architecture of Smart grid is illustrated with detailed explanation. Different

network protocols can be used for different applications depending upon network requirements. A comparative analysis of various communication standards is also included with suitability for specific Smart grid application.

- Though each standard has its own advantages and disadvantages, selection of a specific set of communication standards for Smart grid network depends upon coverage area, type of network, data throughput, security concerns, geographical location etc.
- Microgrid is an important component of Smart grid which expedites the use of renewable energy resources. It can also address the issue of energy scarcity.
- IEEE 802.11 standard is one of the apt choices for IoT based home area network as it supports the Ethernet backbone network. WLAN is a ubiquitous network which makes it suitable for HAN as well as NAN applications. IoT is inevitable for Smart grid communication infrastructure which demands for end to end network connectivity as well as communication between IEDs. The research work provides solution for all three Smart grid hierarchical networks such as HAN, NAN and WAN using prototype development and testing which lays a foundation for actual network design and implementation.
- Smart grid consists of heterogeneous and hierarchical networks with diverse set of communication protocols. Primitive layered approach restricts performance enhancement approaches and methodologies. Cross layer optimization can be used for network performance enhancement. The parameter optimization of IEEE 802.11 protocol has been implemented and provides a novel set of results for HAN and NAN using Riverbed-OPNET network optimization software. The research work includes network design and performance enhancement. It provides a directive for network design and implementation with optimized set of parameters.
- Design and deployment of Smart grid technology will face enormous challenges in terms of interoperability, security, reliability and safety. Diverse set of communication protocols must be interoperable with each other by using some common application program interface. Sizing and integration of distributed energy resources must be carefully addressed.
- Cyber-attacks and EMI hazards are critical challenges for reliable, safe and secured operation of Smart grid infrastructure. Various types of cyber and EMI threats are discussed which can pave the way for future research endeavors.

FUTURE RESEARCH

- Smart grid technology is the most imaginative technology of present era. Realization of this technology entails enormous research endeavors in diverse areas. Some of the future research areas are Cyber security attack penetration and testing, Network optimization techniques, AMI, EMI-EMC analysis, fault analysis, grid stability and reliability analysis, Spectrum sensing and bandwidth optimization, penetration of renewable energy resources, Plug in hybrid electric vehicle etc. Fuel cell is a prominent technology for Smart grid applications and requires further research on integration and operational issues. The research explored in this thesis can be explored using other protocols in future research endeavors.